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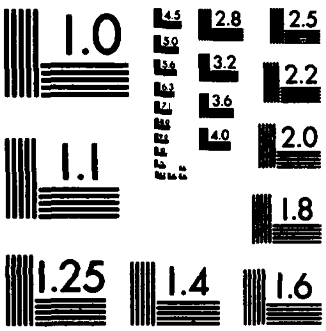

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FINAL SCIENTIFIC REPORT

SHUTTLE FLIGHT TEST OF AN ADVANCED GAMMA-RAY DETECTION SYSTEM

U.S. Air Force Office of Scientific Research
Grant AFOSR-82-0060
to the University of Florida

1 January 1982 - 31 March 1983

by

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November 1983

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Germanium detector

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A detector system consisting of an n-type, high-purity germanium detector in a bismuth germanate anticompton shield has been developed for flight on a space shuttle mission. The BGO shield consists of six trapezoidal segments, each one being 14.6 cm long by 2.74 cm thick, mounted in a hexagonal shape about the axis of the germanium detector can.

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1. Introduction

At the Space Astronomy Laboratory we have developed a Gamma-Ray Advanced Detector (GRAD) Experiment for early flight on a space shuttle mission. This experiment has the following objectives: 1) tests of the performance in space of two new gamma-ray detector elements bismuth germanate (BGO) and n-type, high-purity germanium (nGe), 2) an investigation of the background of gamma radiation induced in the orbiter by exposure to the radiation belts, and 3) the acquisition of high energy-resolution spectra of the sun and the galactic center.

Shortly after the flight of the OSS-1 pallet of scientific experiments[1)] on the third Space Shuttle mission (STS-3) in March of 1982 it came to our attention that the chamber inside the Thermal Cannister Experiment (TCE)[1)] might become available for a new experiment on a proposed reflight of the OSS-1 pallet on the STS-5 mission. NASA officials decided later not to re-fly OSS-1; however our original plan to fly inside the TCE forced certain constraints on the design of GRAD. In the first place it was necessary that the gamma-ray spectrometer mechanically resemble the dummy experiment (a cylinder of water with thermal sensors) it was to replace inside the TCE. Furthermore it had to make use of existing power connections and resemble the TCE to the OSS-1 avionics unit. Finally, the severe time constraint of meeting a June, 1982 delivery deadline in order to make the November launch date for STS-5 required that we use an axially-symmetric, open-ended geometry rather than a more efficient assymetric design for the BGO shield, as the technology of working with BGO was not sufficiently developed for the manu-facturer to guarantee delivery of a shield of the latter type within the time allotted. In spite of these limitations, the GRAD shield is the most advanced BGO anticompton shield to have been fabricated to date.

The two types of gamma-ray detection elements of which the present spectrometer is composed, BGO and nGe, have not yet been tested by actual use for the acquisition of gamma-ray spectra in space, although early use of BGO for another purpose[2)] has been made on a space mission. That BGO has the highest stopping power of any commercially available scintillator, is non-hygroscopic and relatively infragile make it potentially a very useful material for astronomical applications. That nGe may be at least 25 times more resistant to radiation damage than conventional pGe makes it potentially of great usefulness for high resolution work. Hence answers to the questions of how well these detectors will withstand the rigors of launching and operation in orbit, how well they function as detectors in the environment of space, and how susceptible they are to radioactivation and degradation from radiation damage are of considerable importance for the development of the next generation of gamma-ray telescopes.

2. The GRAD Spectrometer

2.1 The Detector System.

The major elements of the detector system are shown in Figure 1. The central detector is a nGe detector (ORTEC GAMMA-X model) having a crystal diameter of 55.6 mm and length of 53.2 mm, enclosed in a specially designed cryostat having a beryllium window which is 0.5 mm thick. In operation without the BGO shield the nGe detector has a resolution of 1.99 keV FWHM at 1.332 MeV, a peak-to-compton ratio of 53 and a photopeak counting efficiency of 30% relative to that of a standard 3" x 3" NaI detector. A matrix of activated charcoal inside the special 30-liter dewar holds the liquid nitrogen in contact with the central cold finger for operation in zero gravity.

The BGO anticompton shield, manufactured by the Harshaw Chemical Company, consists of six trapezoidal segments (14.6 cm long by 2.74 cm thick) arranged in a hexagonal configuration axially about the nGe detector can, as shown in Figure 2. These segments are polished on all sides and joined together with

optically transparent epoxy cement having an index of refraction of 1.54. The base of each segment is then coupled to a Hammamatsu R1213-07 photomultiplier tube.

At the base of the germanium detector housing, inserted between the BGO photomultipliers, is a small calibration probe consisting of a plastic scintillator which has been doped with a weak imbedded source of ^{60}Co and optically coupled to a photomultiplier tube. Beta rays associated with the emission of ^{60}Co gamma rays are detected in the plastic scintillator, resulting in the generation of a pulse which is used to switch the output of the germanium detector to a region of the multichannel analyzer reserved for calibration spectra.

2.2 The Electronics Configuration.

Figure 3 is a block diagram of the electronics circuitry. An energy signal from the nGe detector is first preamplified and then routed to three linear amplifiers which supply 6-μs shaped signals to three separate 4096-channel analog-to-digital converters (ADC's) through three independent single-channel analyzers (SCA's). Each amplifier - SCA - ADC combination is a single circuit board supplied by Canberra Industries and designed originally for use in that company's Series 10 Multichannel Analyzers. These circuits are adjusted such that the first ADC covers the range 30-500 keV in 4096 channels; the second covers the range 30 keV to 2 MeV; and the third, the entire range from 30 keV to 10 MeV. This redundancy reduces the probability of failure and provides adequate keV/channel resolution across the entire spectrum.

The timing logic is determined with fast timing signals from the shield photomultipliers, the calibration probe photomultiplier and the nGe preamplifier. The timing outputs are routed into an array of pulse amplitude discriminators. The nGe PAD has lower- and upper-level discriminators set to cover the range 30 keV to 10 MeV. The BGO PAD has two sets of lower- and upper-level discriminators: one to span the range 30 keV to 10 MeV and the other to define a window around the 511-keV line in the BGO spectrum. Pulses passed through the 511-keV window

are used to overrule the veto in the third (full spectral range) ADC line, so as to prevent the vetoing of pair escape peaks from high-energy gamma rays. The fast timing signals from the two CFD's are routed into a fast coincidence circuit, which then emits stretched pulses to control the gates of the ADC's.

Gamma-ray spectra are accumulated for a preset time in one of two memories. At the end of the preset interval, accumulation is switched to the second memory while data from the first are read into the orbiter's data transfer and telemetry system. On the ground the spectral data are stripped from the telemetry stream and transferred into a LeCroy Model 3500 multichannel analyzer system for further handling.

When a nuclear disintegration occurs in the calibration probe, the fast coincidence logic sends an interrupt to the microprocessor to flag the arrival of a calibration signal from the second ADC, which is then stored in the calibration spectrum.

2.3 Integration into the Orbiter

The GRAD spectrometer will be mounted in a fixed position in the cargo bay of the orbiter. The 66° FWHM field of view of the instrument is large enough that pointing will be done by orientation of the spacecraft. The present plan calls for mounting either directly on the sill of the cargo bay or on a special carrier designed to bolt onto the Getaway Special (GAS) beam.

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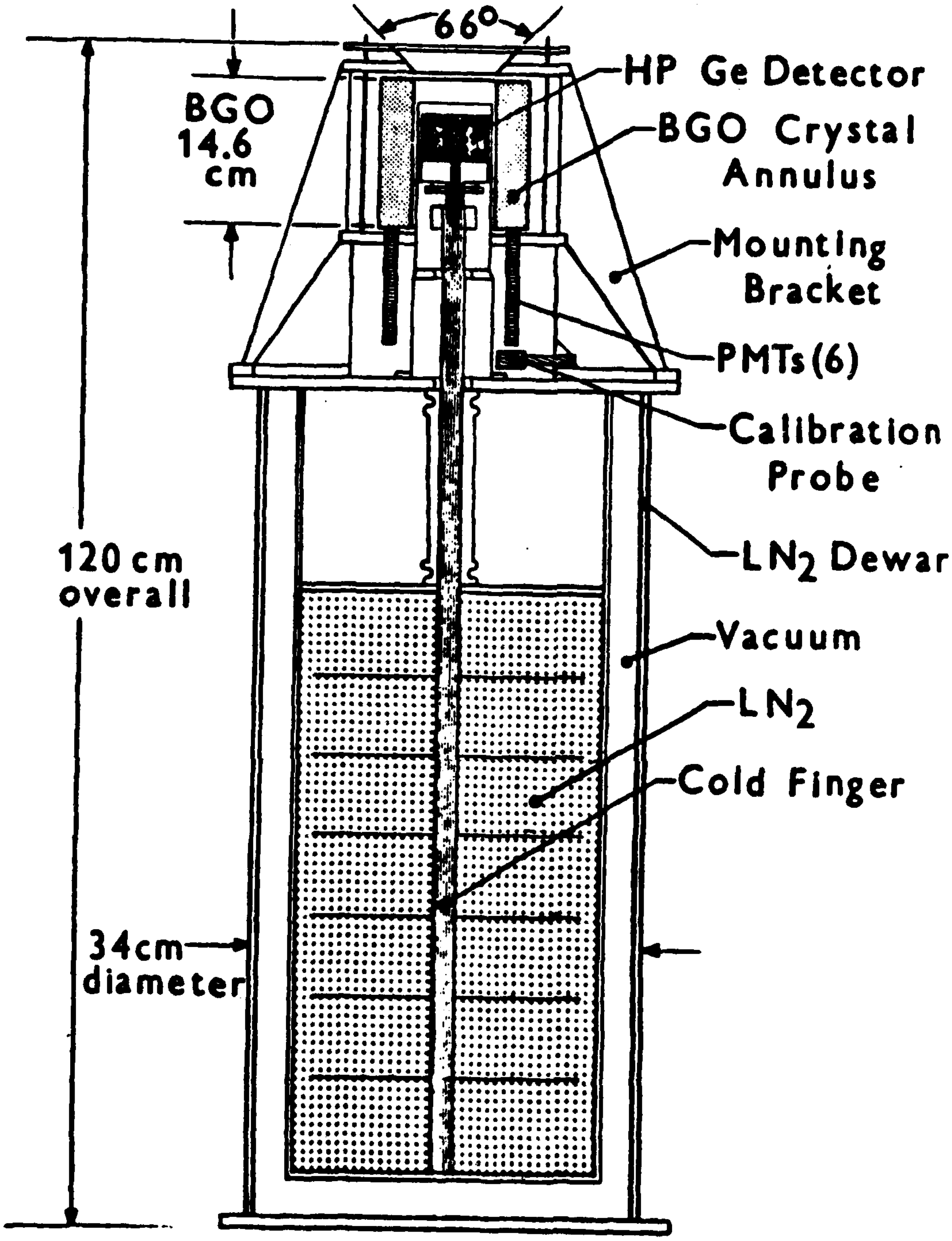
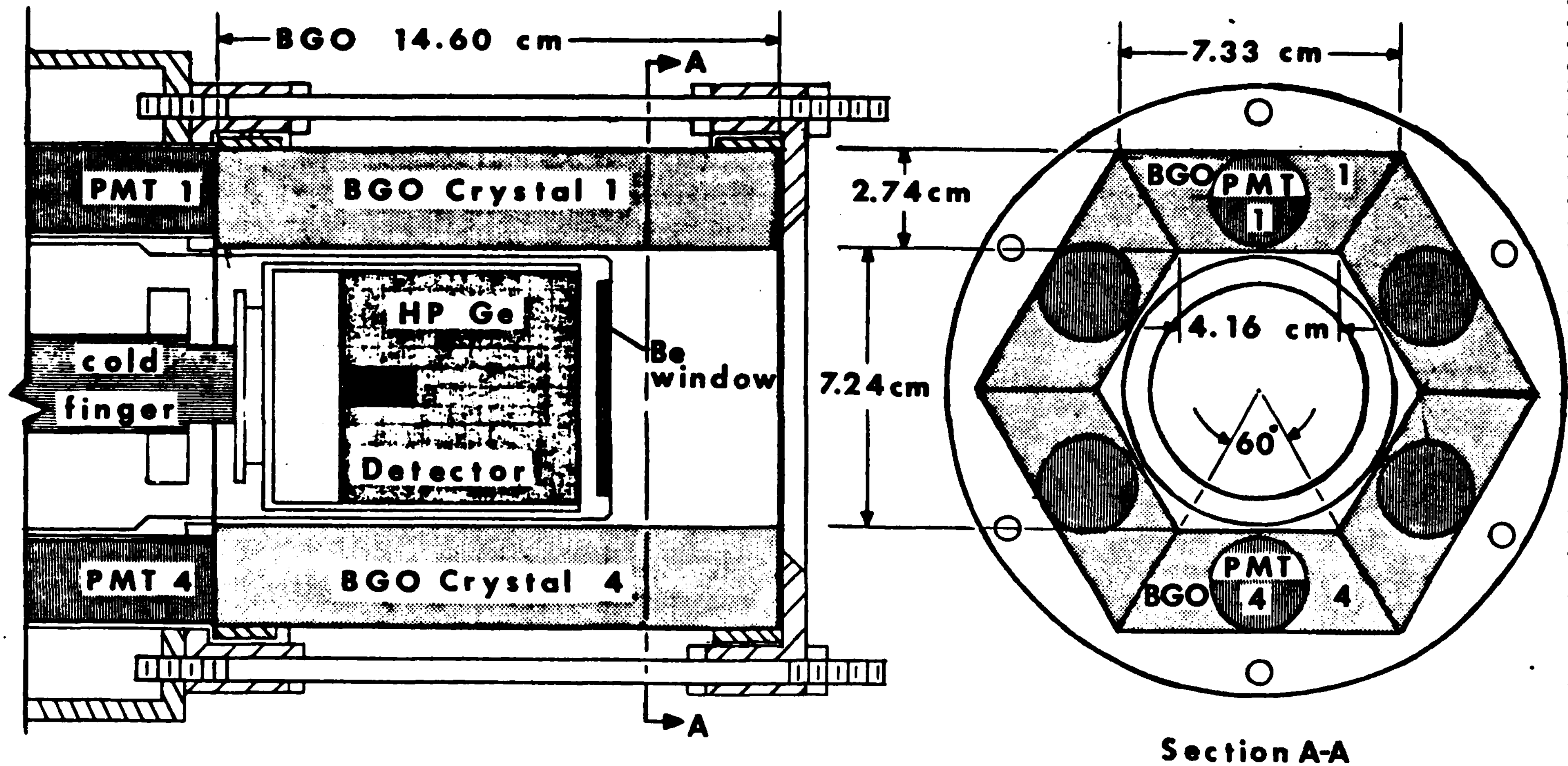

66°
HP Ge Detector
BGO 14.6 cm
BGO Crystal Annulus
Mounting Bracket
PMTs (6)
Calibration Probe
120 cm overall
LN2 Dewar
Vacuum
LN2
Cold Finger
34cm diameter

Figure 1



GRAD BISMUTH GERMANATE SHIELD

Figure 2

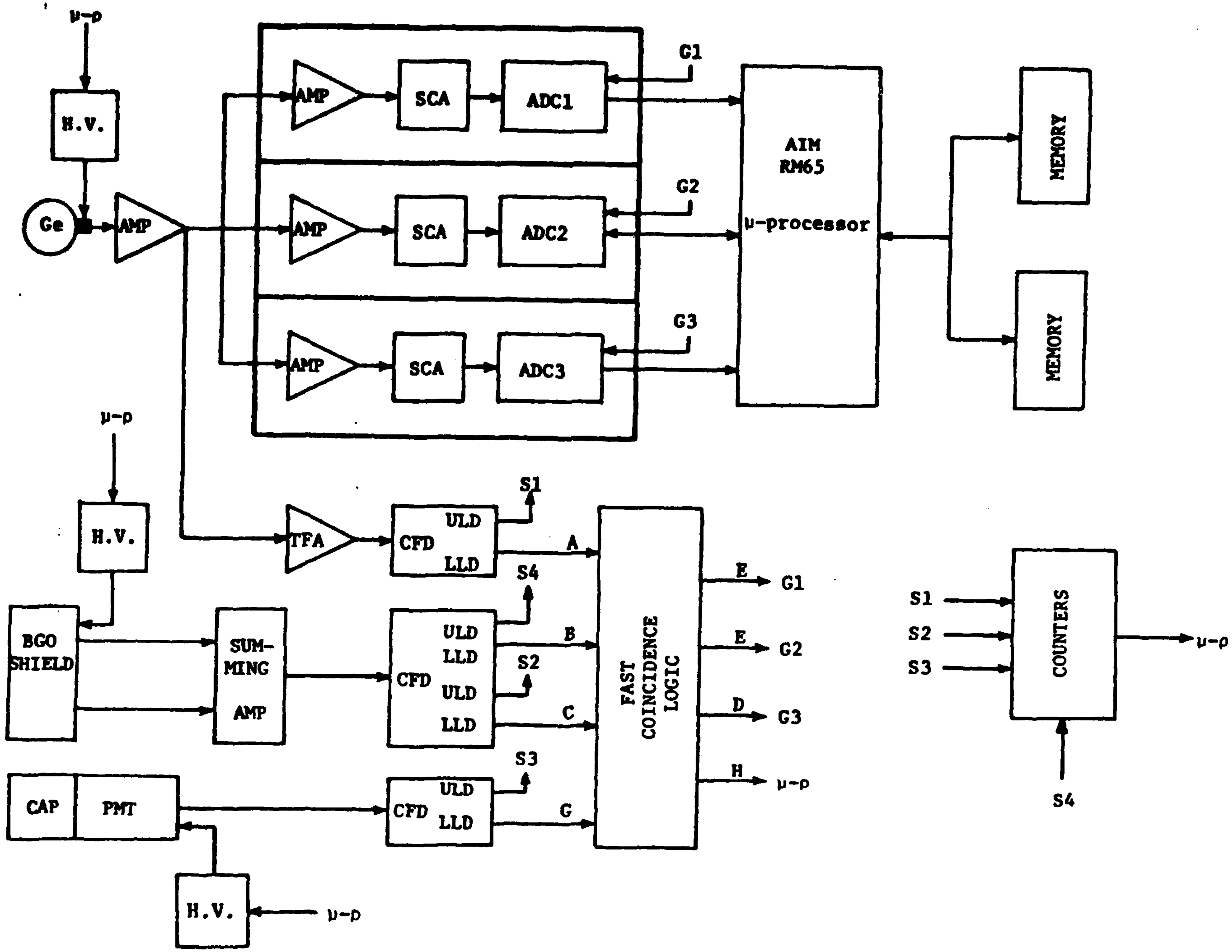

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Figure 3

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